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WiLab:
a large-scale real-life wireless test environment at IBBT

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Outline

- The WBA use case
  - General objective
  - Architecture
  - WSAN solutions
    - Low power consumption
    - Scalability
    - QoS
- WiLab
  - Motivation
  - Topology & features
  - Deployment
  - Initial results
- Conclusion

Wireless Building Automation (WBA)

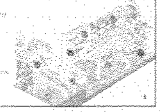
- IBBT research partners
  - UGent-IBCN
  - UGent-MMLab
  - UA-PATS
  - KULeuven-COSIC
  - KULeuven-ICRI
  - VUB-ETRO
  - IMEC
- Industrial partners

Wireless Building Automation (WBA)

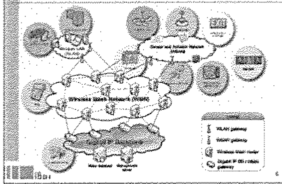
- Some statistics
  - # partners: 14
  - Manpower effort: 611 MM (ca. 51 MY)
  - Budget: 5540 k€
  - Duration: 2,5 years (1/10/06 - 31/03/09)

Wireless Building Automation (WBA)

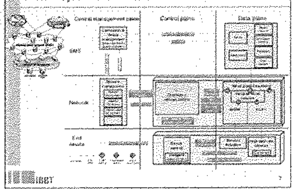
- Target
  - to develop advanced building automation techniques in order to deploy building management systems, hereby:
    - avoiding as much as possible costly and inflexible cable infrastructures
    - covering hard to reach locations such as protected monuments
- Building Management System (BMS)
  - monitor & control of
    - Low data rate applications
      - HVAC control
      - (emergency) lighting
      - access control
      - motion detection
      - fire detection
      - positioning
    - High data rate applications
      - camera surveillance
      - public address (video display, audio)



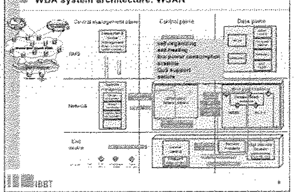
WBA network architecture



WBA system architecture



WBA system architecture: WSAN

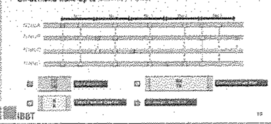


Low-power WSAN

- Goal
  - energy efficiency
  - network lifetime ~ years (2 AA batteries)
- Benefits
  - no power cables
  - low maintenance
- Solutions
  - beacon enabled IEEE 802.15.4 ...
  - ... → network wide synchronization:
    - nodes synchronize by tracking beacons of parent
    - nodes simultaneously wake up/sleep
    - time divided in sync slots

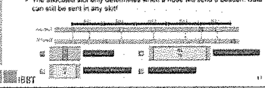
Low-power WSAN → Slotted WSAN (1)

- Beacon enabled network to establish synchronization
  - Time is divided in slots:
    - 1 chance to send a beacon/slot
    - 1 or more chances to send data/slot → Low Latency
  - Routers send beacons periodically in allocated beacon slot
- On-demand wake-up to Minimize Power

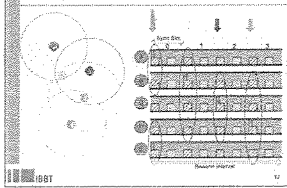


Low-power WSAN → Slotted WSAN (2)

- Routers send beacons periodically in allocated slot
  - Beacons sent without CSMA/CA
  - How do we get a slot that is collision free?
    - Coordinator allocates a slot
      - Not scalable
    - Routers choose a slot using a distributed algorithm
      - Reuse slots → scalable
      - Slot is only unique in 2-hop neighborhood
      - Distributed Assignment of Sync Slots algorithm (DASS)
  - The allocated slot only determines when a node will send a beacon. Data can still be sent in any slot!

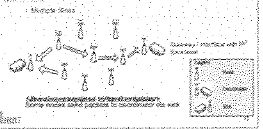


Low-power WSAN: DASS

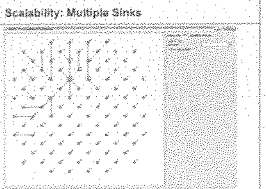


Scalability: Multiple Sinks

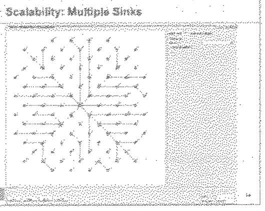
- PROBLEM:
  - nodes far from coordinator have large latencies when sending data to a central sink
- SOLUTION:
  - Multiple Sinks



Scalability: Multiple Sinks

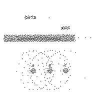


Scalability: Multiple Sinks



Quality of Service (1)

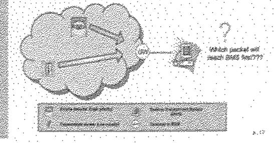
- PROBLEM: diverse applications with different needs
  - Switch: low latency, low reliability
  - Alarm: High reliability, medium latency
  - HVAC: low reliability
- SOLUTION:
  - RTS/CTS
    - Nodes wake up simultaneously
    - Random back-off (RTS) with CTS
    - low latency packets get priority
  - 8 QoSClasses (set by application)
  - 3 'Special function' QoSClasses:
    - Class 0: low reliability, low latency, with TimeToLive
    - Class 1: low latency, medium reliability
    - Class 2: high reliability (end-to-end ack)



Quality of Service (2)

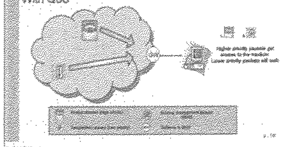
Without QoS

2 Nodes send data simultaneously



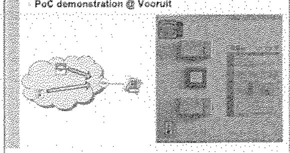
Quality of Service (2)

With QoS



Quality of Service (3)

- PoC demonstration @ Vooruit



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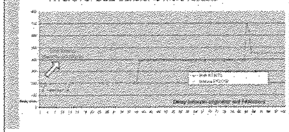
Quality of Service (3)

- QoS:
  - RTS/CTS: Data transfer is more reliable



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WBA results

- Tested algorithms:
  - Protocols developed & validated in simulator (NS 2.29)
  - And ported to hardware for experimental validation
- The WSAN is low-power:
  - Without sleep/wake up scheme (RX always on).
    - Network lifetime ~ weeks (2 AA batteries)
  - With sleep/wake up scheme:
    - Up to 10 years with 2 AA batteries
- Scalability:
  - 100s of nodes with only 64 sync slots / beacon interval
  - Latencies are reduced by introducing extra sinks
- QoS
  - High priority packets reach destination first
  - RTS/CTS for reliable and controllable data transfer

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Motivation for WiLab @ IBBT

- Goal
  - Set up a general purpose testbed with ca. 200 wireless sensor/actuator nodes (DUTs) and deploy them over the Zuiderpoort building
- Why?
  - Network simulations & wireless channel emulations are unreliable due to simplified & inaccurate models (channel, hardware, embedded environment)
  - WSAN protocols are typically designed to run on large scale
  - Evaluations on small scale testbeds are not sufficient (only proof of functionality, not of scalability)
  - → Need for real-life environment
- WiLab is driven by IBBT WBA project
  - Successful demonstration of small-scale wireless sensor/actuator network @ Vooruit
  - Large scale simulations of novel concepts for energy efficiency, QoS support, multiple gateway support, ...
  - → WBA extension: are WBA solutions valid in real-world scenarios with a large number of nodes?

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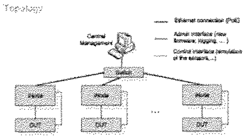
WiLab @ IBBT

- Topology



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WiLab @ IBBT

- Feature set
  - # nodes: 190 fixed locations
  - Every node is generic and is equipped with
    - 3 USB, RS232, VGA interfaces
    - 1 or 2 sensor nodes (IEEE802.15.4 + extensible with sensors: temperature, light, humidity)
    - 2 WiFi (IEEE 802.11 radios (a/b/g))
    - Extensible: Bluetooth, Software Defined Radio, ...
  - Every node is powered via PoE and can be disabled
  - Environment emulator (EE)
    - EE can emulate battery voltage of the sensor nodes and can measure the consumed electrical power real time
    - EE can emulate environmental variables like switches, (sensor) data
    - EE can log the events of the sensor nodes
  - Sensor nodes can measure and react on real and emulated environmental variables
  - Development environment
    - TinyOS (sensor nodes)
    - Click (iNodes)
  - Remote access

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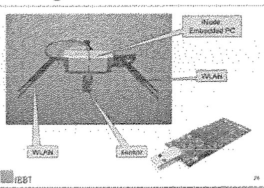
WiLab @ IBBT: hardware



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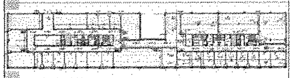
WiLab deployment @ IBBT building



- 190 nodes @ 3 floors
- IBBT central staff open office, different office spaces, meeting rooms, student lab rooms, iLab, corridor, ...
- Also limited set of mobile sensors (on moving robots)
- STATUS:
  - Today
    - ca. 60 nodes deployed & operational
    - Environment Emulator designed & tested
  - March 2008
    - all 190 nodes deployed & operational
    - Integrated Environment Emulator
  - April 2008
    - Mobile robots

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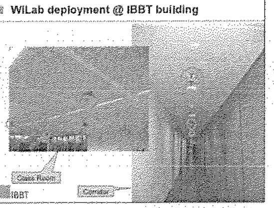
WiLab deployment @ IBBT building



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Initial results @ WiLab: protocol validation

- Validation of WBA solutions
  - RTS/CTS mechanism
    - Simulator environment
      - needed to avoid collisions
      - does not take into account clock drift
    - Real-life environment
      - No need for RTS/CTS to avoid collision for low loads (clock drifts)
      - RTS/CTS still needed for QoS support for low and high load

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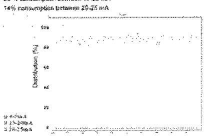
Initial results @ Wilab: Environment Emulator

- Energy consumption for always-on MAC
  - Lifetime: 12 days with 2 AA batteries
    - 86 % consumption between 15-20 mA
    - 14% consumption between 20-25 mA



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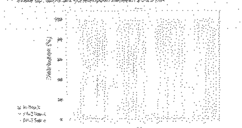
Initial results @ Wilab: Environment Emulator

- Energy consumption for wake up/sleep MAC
  - Lifetime: hundreds of days with 2 AA batteries
    - Sleep: 100 % consumption between 0-5 mA (typ. 1 uA)
    - Wake up: dominant consumption between 20-25 mA



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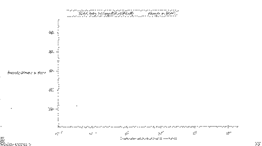
Initial results @ Wilab: Environment Emulator

- Battery lifetime versus communication interval
  - MAC duty cycling needed to safe energy!



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Conclusion

- The IBBT WBA project
  - First successful demonstration of WSAN solutions
    - Small scale experimental validation
    - Large scale validation through simulations
- WiLab @ IBBT
  - Large scale experimental validation of real-world scenarios in real-life environment
  - Rapid prototyping of innovative WSAN solutions
  - Easy & remote access

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Sensor driven State-of-the-Art Mechatronics

Publication date on this website: Thursday, January 31, 2008
Company: DSP Valley
Category: Seminars, Tutorials, Courses, Workshops, Conferences

PHOTO

Summary:
On February 20th, 2008 DSP Valley will organize a seminar about "Intelligent sensor and actuator based systems for mechatronics".

Full Text:
On February 20th, 2008 DSP Valley will organize a seminar about "Intelligent sensor and actuator based systems for mechatronics". This seminar presents the results of a TETRA research project conducted by the Erasmus Hogeschool in Brussels. The goal of this half-day seminar is to provide the audience with an insight in modern, state-of-the-art techniques that are currently being used in high-end mechatronic systems.
Experts, both from the academic as the industrial world will give an overview of the possibilities that the evolution in modern sensor and actuator systems provides for the mechatronic industry. They will focus on a number of specific topics like:

· Reconfigurable systems in the field of mechatronics
· State-of-the-art sensor systems for 'intelligent' applications
· Wireless sensor networks
· Integrated sensor and actuator systems
· ...

Next to that, a number of presenters will provide a sneak-peak in the applications they recently developed. This means that there will be case studies from the industry to illustrate the use of these systems in real-life applications. Hereby, the focus will lie on feasibility, advantages and disadvantages, overcoming technical issues, ...

In parallel to the presentations a mini-exhibition will show products and demos. We will provide time and opportunity to network with the different participants and presenters to allow discussions on details.
The complete program details will soon become available on our website:
http://www.dspvalley.com
All the presentations will be given in English.

Contact:
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